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The contribution degree of sub-sectors to structure effect and intensity effects on industry energy intensity in China from 1993 to 2003

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Abstract

This paper chooses the 36 industry sub-sectors as samplings, based on the data sets of added value and end-use energy consumption from 1993 to 2003 of China. By implying the improved index decomposition methods, ADMI and LMDI, the models are formulated. The results obtained show that structure effect which was less than intensity effect decreased year by year before 1998 and turned into steady from 1999. The intensity effect descended during the whole sampling periods. The biggest contributions on average structure effect and intensity effect were from sub-sectors of electric equipment and machines and raw chemical materials and chemical products, and the smallest contributions were from industries of production and supply of gas and petroleum processing and coking. The paper provides the foundation for policy making on improvement of industry energy efficiency.

Keywords: Energy intensity; Structure effect; Intensity effect; Contribution degree

Contents

1. Introduction

Soon after the 1973 world energy crisis, there have been a variety of studies investigating energy saving, energy efficient use and energy related environment problems. Many countries have speeded up the research and development plans for saving energy in which energy efficiency plays an important role. Energy intensity which is the essential indicator of energy efficiency, at the country view, means the proportion of energy consumption of the whole country to gross domestic product. And at the industry or sub-sector level, it is defined as the proportion of the energy consumption of industry or sub-sector to value-added.

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China has experienced spectacular economic uprising, with 9.79% average rate growth in GDP over the period 1980–2003(NBS, 1981–2004) [1]. Against the upward trend of economy, the energy intensity showed a reversed direction of decline continuously more than 20 years from 14.14 in 1980 to 4.87 in 2001, with 66.2% drop but an upturn since 2002 and reached 4.95 in 2003. Comparing with other developing countries, Chinese energy income elasticity was much lower in these periods [2], which clearly indicated that China used less energy with fixed GDP. The question arises of what drove the decline of energy intensity prior to 2001 and what were the dominant effects to the change of energy intensity since 2002. Researchers demonstrated different issues on theory and empirical results with different samples and methods [3–8].

Smil [3] and Kamibara [4] conducted that the structural shifts away from energy-intensive industrial sub-sectors to less energy-intensive industrial ones was the major cause for the change of energy intensity. Stinton and Levine [5] examined the structural shift and real intensity change in Chinese industrial sector between 1980 and 1990 and found that the latter accounted for 85% of the country's overall industrial intensity vibration. Based on Chinese input–output tables in 1981 and 1987 for China, Lin and Polenske [6] conducted a structural decomposition analysis to explain China's energy use changes between 1981 and 1987. Their conclusion was that comparing to 1981 all the energy savings in China in 1987 can be attributed to energy efficiency improvements [6]. Zhang [7] proposed decomposition method of giving no residual noted as Laspeyres of choosing the samples of China's industrial sectors from1990 to 1997, showed that 88% of the cumulative energy savings in the industrial sector was attributed to real intensity change and the 12% contribution was from structure shifts. For the decline of energy intensity in China, Fisher-Vanden et al. [8] identified three broad explanations (1) sectoral change (2) sub-sector energy productivity gains and (3) inaccurate statistics. The statistic error was thought mainly from the emission account of coal produced by small coalmines that have been officially shutdown and imported fuels [8].

From the previous literatures, we see although the driving forces influencing the change of energy intensity were obtained, the energy scholars studied on the in-depth industry sub-sector views of China that have, to date, been rare and led to the conclusions and suggestions difficult to carry on. The major difficulty of in-depth research may come from the miscellaneous data sets. Since the revision of the data of energy consumption, the poor data before adjustment may be partly to blame for the swing of previous studies. Moreover, the driving factors would fluctuate as time goes on and the latest study chose the data of China that was just from 2000 [9]. While from 2001 the energy intensity of China terminated the state of 20 years drop and took a signified turn to rise [2]. In order to be high degree of sub-sectoral research and aid in optimizing fuel-mix and industry structure, with the change of the energy intensity of China from 1993 to 2003, the objective of this paper is to reveal the structure effect and intensity effect influencing the viability of industry sub-sector energy intensity from 1993 to 2003 by applying improved index decomposition. The further purpose is to list the contribution degree of every industry sub-sector to the two effects by implying contribution degree indexes.

The article is laid out as follows. Section 2 describes the basic method, Section 3 discusses the data and samples used and Section 4 applies the improved decomposition method to the data to analyze the driving factors for the changes of energy intensity form 1993 to 2003 and estimates the contribution degree of the sub-sectors to the two forces. Section 5 offers conclusions and instruction, gives the suggestions and proposes further studies.

2. Methodology

Decomposition methodology has become a useful and meaningful tool in energy and energy related environmental analysis. It can be seen from the foregoing that the decomposition methodology is a technique that provides a linkage between an aggregate and the original raw data whereby information of interest is captured in a concise and usable form. Divisia [10] proposed Divisia index decomposition and more detailed interpretation can be found in [11]. Boyd et al. [12,13] proposed the multiplicative and addictive form arithmetic mean Divisia index (AMDI). Meanwhile in late 1970s, the Laspeyres index was developed and then quite widely adopted by academicians in the early 1980s. But after 1995, the Laspeyres index decomposition was seldom used as its main drawbacks are that it fails to pass the time reversal test and the residual arising from the interactions among factors in the decomposition would be too large to be accepted [14]. For example, the residual, brought about by Park [15] applying this method, was as high as 1322%, which led to difficulty in interpreting the result. Otherwise Divisia explains relative value while Laspeyres explicates absolute value. While the samples are time series, the Divisia index decomposition is more adaptive. By the requirement of practice and deep research on theory, some scholars continuously improved the index decomposition. They also compared different methods systematically and developed both in the methodological and application fronts. In 2001, Ang and Liu [16] proposed the logarithmic mean Divisia index (LMDI) which was perfect in decomposition and consistent in aggregation. Ang [17] discussed the properties of Divisia index and the Laspeyres index, concluded by recommending the multiplicative and additive LMDI methods due to their theoretical foundation, adaptability, ease of use and result interpretation, and some other desirable properties in the context of decomposition analysis. A practical guide for the use of LMDI was provided subsequently [18]. Ang and Liu [19] proposed and proved that replacing the zero value by a small number δ = 10–20 would give satisfactory decomposition results for index decomposition method. The settlement of handling zero-problem modified the LMDI method. In this paper, therefore, we first present two general methods for decomposing the energy intensity for industry sub-sectors, one popular conventional decomposition method AMDI and one recently proposed perfect decomposition method LMDI.

2.1. Basic model

There are two pacing factors in deciding the industry energy intensity. One is the real intensity of sub-sectors which represents the amount of energy consumption that is required to yield a given level of output at the sectoral level. The other is the proportion of value-added which means the share of the sub-sector in the total output of industry. The aggregative energy intensity in t year is decomposed as follows:

$$I_t = \frac{E_t}{Y_t} = \frac{\sum E_{it}}{\sum Y_{it}} = \sum_i S_{i,t} I_{i,t} \tag{1}$$

The first term I_t is the whole industry energy intensity in t year; E_t is the total industrial energy consumption; Y_t is the total industrial value-added. $E_{i,t}$ is the energy consumption in sector i; $Y_{i,t}$ is the production of industrial sector i; $S_{i,t}$ is the production share of sector i; $I_{i,t}$ is the energy intensity in sub-sector I ($E_{i,t}/Y_{i,t}$).

The Eqs. (2) and (3) express the aggregative energy intensity D_{tot} which changes from I_0 in 0 time to I_t in t time by multiplicative and addictive form. D_{str} and D_{int} respectively represent the estimated impact of structure shifts and sectoral intensity. Ang and Zhang [20] indicated that the choice between multiplicative and additive decomposition was inconsequential methodologically and the differences lay in the quality of ease of the result presentation and interpretation. When decomposition is performed on a yearly basis over a period, it is more handy to use the multiplicative approach as the decomposition results, often given in indices, can be convenient plotted over time. Thereby, we choose the multiplicative form in this paper.

$$D_{\text{tot}} = \frac{I_t}{I_0} = D_{\text{str}} D_{\text{int}} \tag{2}$$

$$\Delta_{\text{tot}} = I_t - I_0 = \Delta_{\text{str}} + \Delta_{\text{int}} \tag{3}$$

2.2. AMDI

Based on the above-mentioned general decomposition, we employ the weigh $W_i = E_{it}/E_t$ and theorem of instantaneous growth rate to Eq. (1). Involving in time from 0 to T is showed as:

$$\frac{\mathrm{d}\ln(I_t)}{\mathrm{d}t} = \sum_i w_i \left[\frac{\mathrm{d}\ln(S_{i,t})}{\mathrm{d}t} + \frac{\mathrm{d}\ln(I_{i,t})}{\mathrm{d}t} \right] \tag{4}$$

$$\ln\left(\frac{I_t}{I_0}\right) = \int_0^T \sum_i w_i \left[\frac{\mathrm{d}\ln(S_{i,t})}{\mathrm{d}t} \right] + \int_0^T \sum_i w_i \left[\frac{\mathrm{d}\ln(I_{i,t})}{\mathrm{d}t} \right] \tag{5}$$

Indicated by multiplicative form, Eq. (5) can be expressed:

$$D_{\text{str}} = \exp\left\{ \int_0^T \sum_i w_i \left[\frac{\mathrm{d}\ln(S_{i,t})}{\mathrm{d}t} \right] \right\} \tag{6}$$

$$D_{\text{int}} = \exp\left\{ \int_0^T \sum_i w_i \left[\frac{d\ln(I_{i,t})}{dt} \right] \right\} \tag{7}$$

The weight function is usually adopted by the arithmetic mean of the weights for year 0 and year T, Eqs. (6) and (7) are developed. The formulas are:

$$D_{\text{str}} = \exp\left\{ \sum_i \frac{(w_{i,t} + w_{i,0})}{2\ln(S_{i,t}/S_{i,0})} \right\} \tag{8}$$

$$D_{\text{int}} = \exp\left\{ \sum_i \frac{(w_{i,t} + w_{i,0})}{2\ln(I_{i,t}/I_{i,0})} \right\} \tag{9}$$

As the existence of residual of this method, Eq. (2) is revised to: $D_{\text{tot}} = D_{\text{str}} D_{\text{int}} D_{\text{rsd}}$. D_{rsd} is the residual.

2.3. LMDI

The logarithmic means two positive number x and y, $L(x,y) = (y - x)/\ln(y/x)$. This weight function was first mentioned in [21]. Sato [22] independently found that this function could be used to discretize the integral Divisia index formulae to give an ideal index. Using this weight scheme, Eqs. (8) and (9) can respectively be transformed into:

$$D_{\text{str}} = \exp\left\{ \sum_i \frac{L(w_{i,t} + w_{i,0})}{\sum_i L(w_{i,t} + w_{i,0})} \ln\left(\frac{S_{i,t}}{S_{i,0}}\right) \right\} \tag{10}$$

$$D_{\text{int}} = \exp\left\{ \sum_i \frac{L(w_{i,t} + w_{i,0})}{\sum_i L(w_{i,t} + w_{i,0})} \ln\left(\frac{I_{i,t}}{I_{i,0}}\right) \right\} \tag{11}$$

Eqs. (10) and (11) give perfect decomposition with no residual, accommodate zero values in the data set, and are consistent in aggregation that ensures the decomposition.

3. Data

Taking account of the availability of the data and the detailed classification of sub-sectors, we select the China's industry sub-sectors between 1993 and 2003 as samplings. According to the classification of National Economy Industry Category Standard (GB/T4754-2002), the two codes industry includes four categories which are mining and quarrying, manufacturing, electric power, gas and water production and supply. But the three codes sub-sectors industry divided by four two codes industry are not in accordance from different years given by China's National Bureau of Statistics (NBS). Mining of other ores, manufacture of artwork and other manufacturing, manufacture of artwork and other manufacturing logging and transport of wood and bamboo are abandoned as these sub-sectors only presented 1 or 2 years. With the small absolute value of energy consumption, the eliminated sub-sectors will not have much impact on energy structure and intensity analysis. The residual 36 sub-sectors as sampling all came to appearance during the chosen periods. The time-series from 1993 to 2003 are chosen instead of a period as to involve yearly decomposition. The reason for choosing 1993 as a starting year is that before 1993 the separation of sub-sectors was not in accordance with those after 1993. Meanwhile by two reasons industry as researching target can be put into use. First, the

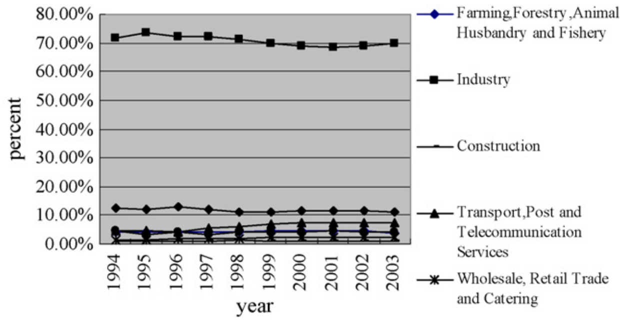

Fig. 1. Energy consumption share.

industry consumed most of China's energy. Fig. 1 shows the tendency of energy consumption structure. During the last decade, industry energy consumption took about 70% shares over time of the total energy consumption and researches showed that this tendency would not reverse in short time [23]. Second, the detailed classification affords us the opportunity to further insight in the sub-sector energy intensity as the sub-sector decomposition is more effective than aggregate decomposition which focuses on nation views. The cross sub-sector decomposition is usually characterized by large variations in both value-added and energy consumption, which arises from inherent differences between the sub-sectors compared. All the total industrial value-added data retrieve from every years of China's Statistical Yearbook as published by NBS and the energy consumption data come from China's Energy Statistical Yearbook also as published by NBS.

Table 1 lists the energy intensity of 36 sub-sectors during the research periods. It shows that except for nonmetal minerals mining and dressing and chemical fiber's separately rising 29.02% and 15.53%, other sub-sectors' energy intensity all went down throughout the study period. Comparing to 1993, by 2003 the energy intensity of gas production and supply with fastest falling speed was at 94.69% declining rate. Leather, fur, down and related products were then after with 75.30% drop. The energy intensity of 36 sub-sectors average fell down 50.61% during the same years. In comparison with the lateral direction, the maximum energy intensity was Gas Production and Supply before 2000. Since 2001 it turned to Smelting and Pressing of Ferrous Metals, while the lowest energy intensity was always Tobacco Processing with 0.3534 and then was Garments and Other Fiber Products with 0.7061.

4. Results and discussion

4.1. Index decomposition result and analysis

Taking 1993 as basic year, based on the data sets of value added and end-use energy consumption for the 36 industrial sub-sectors, applying the above ADMI and LMDI method to proceed decomposition analysis of the value-added and energy consumption from 1993 to 2003. As illustrated in Table 2, the D_{tot} concluded from both methods kept increasing during 1994–1996, but decreased to the point of below 1 in 1997 and maintained the downward trend year after year. Before 1998 D_{str} was smaller than D_{int}, which meant that the structure effect contributed more than intensity effect. In other words it demonstrated that intensity decrease or energy efficiency enhancement by industrial sub-sectors itself contributed less than structure transformation of industrial department. But this phenomenon reversed since 1999 and D_{str} was larger than D_{int} till 2003. The margin between the structure effect and intensity effect in 1996 was the smallest but started to enlarge continuously since 1998.

The results may be explained by that since the second half year of 1993 Chinese government began to deflate and from 1994 to 1999 the GDP growth rate declined 1% annually and stimulated the adjustment of economic structure. But since the second half year of 2002, China experienced the third new rapid economic growth cycle after its launching open-door policy, accompanied by the process of acceleration of industrialization and urbanization. The investment and consumption have been the two forces driving the economic development since 2002. In 2003, the GDP and the fixed assets of investment grew respectively at a rate of 9.1% and 26.7% comparing with 2002. Moreover the investment mainly flew to the greater energy-intensive sectors such as steel, cement, and non-ferrous metals. Otherwise the export of energy-intensive products increased quickly since 2002 such as iron and steel wire, plat glass, steel product, iron and steel wire, zinc and zinc alloys. With reference to the fluctuation of intensity effect, it may be pulled by the technology improvement as the capital of research development investment increased from 22.56 billion in 1993 to 94.46 billion in 2003 [24].

Measured as the differences between the two methods, it can be concluded, as shown in Table 2, that D_{rsd} value of LMDI is 1, which means perfect decomposition is certified, while that of ADMI is less than 1, which means the existence of residual. Through the measurement of differences between the two methods, the D-value from two methods of structure effect reached the highest with 0.0039 in 2000 and 2002. It came to the lowest with 0.0001 in 1994. D-values in other years varied within above lowest-highest points. Referring to absolute value the structure effects obtained by AMDI was a little bit larger than that estimated by LMDI. On intensity effect the results by the two methods only came to the coincidence in 1996, reached the highest point with 0.0008 in 2001 while it in any other year was lower. With reference to longitudinal view, the structure effect declined from 1994 to 1998, fluctuated a little in the following 4 years and rose in 2003, while the intensity effect moved up before 1996 and decreased dramatically since 1997. By ADMI the intensity effect decreased from 0.9386 in 1997 to 0.5403 in 2003 and through LMDI it declined from 0.9379 in 1996 to 0.54 in 2003. Comparing the two methods synthetically, it can be said, that the difference between the two methods' result are rather small.

4.2. Contribution degree of sub-sector to intensity effect and structure effect

In order to better analyze impulsion of improvement of industrial energy intensity, it is essential to construct the two

Table 1
Energy intensity of sub-sectors

Sub-sector	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Coal mining and processing	7.8358	10.9096	9.1877	8.8588	8.1378	9.2177	7.6541	6.9984	5.8008	4.6160	4.6840
Petroleum and natural gas Extraction	4.1629	4.1938	2.9942	3.1447	3.0682	2.8260	2.4577	1.6971	1.9840	2.3323	1.9337
Ferrous metals mining and dressing	9.4401	7.0312	6.5308	6.2973	5.9470	6.7212	6.1791	5.3576	4.8579	4.6343	3.7904
Nonferrous metals mining and dressing	5.4133	5.4463	4.9064	5.4309	3.5131	3.3735	2.8441	2.6900	2.8787	2.8344	3.2118
Nonmetal minerals mining and dressing	3.7005	4.0910	4.1321	3.7596	2.9965	4.7925	4.5891	4.6963	4.9560	4.5936	4.7742
Food processing	2.9029	2.6295	3.9716	2.8561	2.3462	2.7720	2.1151	1.6804	1.5655	1.1950	1.0556
Foods production	6.9042	5.2993	5.7209	4.5743	2.7790	3.0014	2.8522	2.0643	1.9446	1.3546	1.2917
Beverages production	3.1717	3.0258	2.8286	2.4779	1.3852	1.5368	1.1872	0.9979	0.9872	0.4974	0.8833
Tobacco processing	0.5134	0.3705	0.3653	0.5092	0.3128	0.2764	0.3332	0.2694	0.2424	0.1726	0.1684
Textile industry	3.3245	3.0785	3.9314	3.5948	2.7554	2.7933	2.2405	1.9617	1.9312	1.8299	1.8195
Garments and other fiber products	0.7827	0.7777	0.9480	0.7414	0.5981	0.6950	0.6161	0.5031	0.4838	0.4794	0.4359
Leather, fur, feather and related products	1.6651	1.2906	1.4387	0.7241	0.5482	0.7393	0.6626	0.5370	0.4829	0.4508	0.4113
Timber processing, bamboo, cane, palm and straw products	3.9325	3.5266	3.9976	2.7352	1.9937	2.7556	2.3035	1.8130	1.6631	1.4805	1.5822
Furniture manufacture	1.9768	1.8030	1.8746	2.2291	1.8195	1.0446	1.1744	0.8835	0.8121	0.6312	0.5920
Papermaking and paper products	12.7923	10.3290	9.2049	7.5457	5.7332	6.0071	4.8968	4.4266	4.0794	3.8190	3.4796
Printing and record media reproduction	1.3305	1.5705	1.6511	1.2916	0.9392	0.9418	0.8879	0.8876	0.8269	0.7064	1.0916
Manufacture of articles for culture, education and sport activity	1.1860	0.7763	0.6801	0.7680	0.6062	0.9878	0.7397	0.7058	0.7266	0.7555	0.5898
Petroleum processing and coking	7.5146	8.2707	9.9171	7.6602	12.0114	12.9944	12.0013	9.4052	8.8744	8.4458	6.9831
Raw chemical materials and chemical products	20.1229	20.4262	16.7829	18.9608	13.1045	12.7301	10.5879	8.9695	8.0483	7.7882	6.9413
Medicines and pharmaceutical products	3.6001	4.2170	4.5395	3.2159	2.0289	1.9093	1.5475	1.1988	1.1643	1.0130	1.0010
Chemical fibers	6.4506	5.7871	6.2965	6.3533	6.7655	8.6657	6.0919	5.6740	7.6773	7.8044	7.4525
Rubber products	4.7657	4.5565	4.6553	4.2164	2.9732	3.2559	2.8935	2.6392	2.6011	2.1999	1.9961
Plastics products	2.1145	2.4415	2.4076	2.1937	1.9086	1.7713	1.4558	1.3218	1.2088	1.0865	1.0726
Nonmetal mineral products	12.4459	13.3292	14.5125	14.3833	11.1071	12.7980	10.9135	8.9648	8.2362	7.7820	7.2357
Smelting and pressing of ferrous metals	10.8125	11.8863	17.5931	21.1222	17.6813	17.3094	15.6855	12.9248	11.1993	10.7394	8.5230
Smelting and pressing of nonferrous metals	9.2200	9.6992	9.4083	11.2800	10.5619	10.1888	8.7399	7.0305	6.5855	6.9847	5.9960
Metal products	2.3250	2.1058	2.5886	2.4918	2.0213	2.0555	1.9173	1.7450	1.7234	1.7611	1.7502
Ordinary machinery	2.5909	2.5878	2.4644	2.7515	1.9596	1.9644	1.5549	1.2938	1.1954	1.1493	0.9842
Equipment for special purpose	2.3636	2.2480	2.4243	2.2014	1.6294	1.7020	1.5284	1.2804	1.1842	1.0010	0.9167
Manufacture of transport equipment	1.7559	1.6080	1.7097	1.7736	1.5093	1.3350	1.0888	0.9659	0.8818	0.7147	0.5709
Electric equipment and machinery	1.0447	1.0647	1.0423	0.9726	0.7878	0.7021	0.5719	0.4532	0.4306	0.4578	0.4397
Electronic and telecommunications equipment	1.1658	0.7667	0.5062	0.5677	0.5423	0.4585	0.4384	0.3441	0.3357	0.3169	0.2998
Instruments, meters cultural and office machinery	1.4033	1.1497	1.1635	1.1455	0.5594	0.7872	0.7763	0.6397	0.5716	0.5666	0.4476
Electric power, steam and hot water production and supply	5.4678	7.0713	5.7761	7.8306	6.1872	4.9838	4.4112	4.1608	3.6075	3.5220	3.6816
Gas production and supply	128.2692	107.2294	109.5686	51.7091	40.0223	36.1702	18.3405	16.1175	10.1635	10.3158	6.8145
Tap water production and supply	7.0412	6.8062	5.8308	4.9863	4.9274	4.3734	3.9725	3.7281	3.5380	3.1810	2.8817

indexes of contribution degree of intensity effect and structure effect. It will be easier when we firstly solve contribution degree of sub-sector intensity effect which reflects share of the energy saving arising from the decline of energy use per unit of output to total energy saving, which can be demonstrated by the following form:

$$\lambda_i = \frac{S_i \times (I_i^0 - I_i^t)}{\sum_i S_i \times (I_i^0 - I_i^t)} \quad (i = 1, 2, \ldots, 36), \quad (t = 1, 2, \ldots, 11) \tag{12}$$

Where λ_i is the contribution degree of energy consumption intensity at i sub-sector; S_t is the proportion of i sub-sector's added value to value-added of industry; I_i^0 is the energy intensity at i industry in base year and I_i^t is the energy intensity in the t year. By Eq. (12), the results are shown in Table 3 using 1993 as base year.

According to Table 3, the largest contribution degree of intensity effect was smelting and pressing of ferrous metals before 1996 but from 1997 raw chemical materials and chemical products located first. The industry that contributed most to intensity effect varied in different years distributing dispersedly, which includes papermaking and paper products, raw chemical materials and chemical products, petroleum processing and coking, chemical fiber and smelting and pressing of ferrous metals. From the view of time series, the

Table 2
Decomposition of energy intensity (1993 as base year)

	ADMI				LMDI			
	D_{tot}	D_{str}	D_{int}	D_{rsd}	D_{tot}	D_{str}	D_{int}	D_{rsd}
1994	1.0233	0.9744	1.0505	0.9997	1.0233	0.9743	1.0503	1.0000
1995	1.0691	0.9679	1.1055	0.9991	1.0691	0.9669	1.1057	1.0000
1996	1.0795	0.9453	1.1429	0.9991	1.0795	0.9444	1.1429	1.0000
1997	0.8608	0.9205	0.9386	0.9962	0.8608	0.9178	0.9379	1.0000
1998	0.8323	0.8781	0.9513	0.9963	0.8323	0.8753	0.9508	1.0000
1999	0.7186	0.8805	0.8200	0.9952	0.7186	0.8768	0.8196	1.0000
2000	0.6015	0.8764	0.6901	0.9946	0.6015	0.8725	0.6895	1.0000
2001	0.5551	0.8805	0.6339	0.9947	0.5551	0.8768	0.6331	1.0000
2002	0.5241	0.8786	0.5997	0.9946	0.5241	0.8747	0.5992	1.0000
2003	0.4845	0.9003	0.5403	0.9960	0.4845	0.8973	0.5400	1.0000

contributing degrees of other sub-sectors were all positive except nonmetal mineral mining and dressing, petroleum processing and coking and chemical fiber. The reason was that the sign was determined by the change of energy intensity of sub-sectors. During the researching time, the average largest contribution degree of intensity effect was raw chemical materials and chemical products with 28.53%. After it was nonmetal mineral products with 11.77%, the average smallest

Table 3
Contribution degree on intensity effect

Sub-sector	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Coal mining and processing	34.5966	11.5766	6.8401	−2.0564	−8.8217	0.4079	1.0606	2.4129	3.6033	3.3775
Petroleum and natural gas Extraction	0.5956	−15.7045	−9.7604	12.0986	16.8308	9.7457	11.8305	7.4660	4.3180	4.9527
Ferrous metals mining and dressing	−2.4875	−1.7091	−1.7758	1.9631	1.5641	0.6873	0.5524	0.5621	0.5048	0.7684
Nonferrous metals mining and dressing	0.0759	−0.8234	0.0220	2.4185	2.4082	1.2869	0.8267	0.6099	0.4736	0.3638
Nonmetal minerals mining and dressing	1.3577	0.8270	0.1003	1.2041	−1.2833	−0.4179	−0.2653	−0.2672	−0.1550	−0.1627
Food processing	−4.3276	7.5921	−0.3448	4.1565	0.9466	2.3848	2.2182	2.1438	2.7926	2.5205
Foods production	−8.9846	−3.5741	−6.6387	13.9080	13.4581	5.5479	4.3719	3.8030	4.7261	3.4830
Beverages production	−1.2387	−1.7358	−3.0540	9.5173	9.4308	4.6198	2.9223	2.3819	4.3378	1.6944
Tobacco processing	−2.0288	−1.2975	−0.0302	1.5794	2.2288	0.6387	0.4960	0.5028	0.6276	0.5050
Textile industry	−7.0606	7.7971	2.7647	6.0770	5.7349	4.8115	3.7681	3.2805	2.9682	2.6694
Garments and other fiber products	−0.0451	0.8214	−0.1881	0.8183	0.4480	0.3349	0.3594	0.3490	0.2736	0.2957
Leather, fur, feather and related products	−1.9457	−0.6526	−2.6913	3.1053	2.6834	1.1299	0.7930	0.7859	0.6880	0.6896
Timber processing, bamboo, cane, palm and straw products	−1.0377	0.0885	−1.7396	3.1514	1.4056	0.8603	0.7254	0.7430	0.6539	0.5811
Furniture manufacture	−0.2624	−0.0826	0.2057	0.1338	0.7583	0.2486	0.2253	0.2324	0.2283	0.2357
Papermaking and paper products	−12.1370	−11.9214	−16.8827	22.8718	22.9633	11.1551	7.4989	7.0215	6.2386	5.9042
Printing and record media reproduction	0.7671	0.5650	−0.0645	0.7016	0.7537	0.3481	0.1938	0.2085	0.2124	0.0743
Manufacture of articles for culture, education and sport activity	−0.8243	−0.6598	−0.5173	0.7249	0.2968	0.2486	0.1620	0.1402	0.1072	0.1386
Petroleum processing and coking	8.4333	19.2932	0.7689	−25.9025	−30.7325	−10.5249	−3.2358	−2.0379	−1.1384	0.6366
Raw chemical materials and chemical products	6.1788	−45.0415	−13.6088	79.8601	86.5439	46.1052	34.3027	32.8077	27.9777	30.2224
Medicines and pharmaceutical products	3.9859	3.5559	−1.3296	6.1821	7.7678	4.1995	3.3058	2.9864	2.6292	2.4778
Chemical fibers	−2.9250	−0.4474	−0.1825	−0.6310	−4.3399	0.3599	0.4988	−0.4623	−0.4104	−0.2751
Rubber products	−0.7435	−0.2184	−1.0092	3.5936	3.2537	1.5075	1.0112	0.9121	0.9140	0.9532
Plastics products	1.8618	0.9437	0.2565	0.7051	1.2900	1.0150	0.7997	0.8378	0.8097	0.7397
Nonmetal mineral products	21.3756	26.6001	20.4375	14.1700	−3.3965	6.1162	8.5188	8.6571	7.7535	8.4776
Smelting and pressing of ferrous metals	35.5972	102.1754	98.1164	−67.3450	−67.7536	−20.9371	−5.9605	−1.0043	0.1602	6.0147
Smelting and pressing of non-ferrous metals	3.2428	0.8137	6.1278	−3.9930	−3.4155	0.7727	2.4387	2.6426	1.7041	2.7054
Metal products	−2.4786	1.4477	0.8161	1.5003	1.4422	0.8760	0.7679	0.7282	0.5777	0.5191
Ordinary machinery	−0.0536	−1.2112	1.1348	4.7972	4.6337	3.0606	2.3684	2.3010	2.0237	2.3133
Equipment for special purpose	−1.4582	0.3901	−0.8225	3.8283	3.4078	1.7117	1.3670	1.2749	1.2970	1.3570
Manufacture of transport equipment	−2.8692	−0.5321	0.1577	2.3720	4.8248	3.1629	2.2711	2.4232	2.7598	3.1929
Electric equipment and machinery	0.2984	−0.0214	−0.5196	2.0133	3.1974	1.8835	1.5822	1.4365	1.1325	1.1388
Electronic and telecommunications equipment	−4.9657	−5.9903	−3.9957	5.3786	8.4143	3.8966	3.2554	2.8672	2.6056	2.8060
Instruments, meters cultural and office machinery	−0.8414	−0.4204	−0.3728	1.1992	1.1015	0.4496	0.3556	0.3604	0.3046	0.3956
Electric power, steam and hot water production and supply	33.7262	5.3846	28.0782	−11.1916	9.6323	9.0772	6.6112	8.5129	7.5013	5.9923
Gas production and supply	7.0108	3.6226	1.8497	−1.1966	−1.1841	1.4454	0.9170	1.4178	7.9956	1.5035
Tap water production and supply	−0.3886	−1.4511	−2.1483	2.2866	3.5063	1.7842	1.0858	0.9627	0.8036	0.7381

Table 4
Contribution degree on structure effect

Sub-sector	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Coal mining and processing	0.3397	−3.4554	−1.7724	0.3865	0.2007	0.0556	0.2588	0.4219	0.4257	0.3419
Petroleum and natural gas extraction	0.0949	−6.2039	−2.2710	3.8327	6.3525	4.8905	11.3054	4.1356	1.1626	1.3497
Ferrous metals mining and dressing	−0.1149	−0.1342	0.2082	−0.0579	0.0505	0.1021	0.0840	0.0620	0.0661	−0.1518
Nonferrous metals mining and dressing	0.0011	0.1625	−0.0032	−0.2000	0.1873	0.0776	0.0964	0.1115	0.1395	0.1180
Nonmetal minerals mining and dressing	0.1720	0.1558	0.0087	0.1781	−0.5934	−0.2020	−0.1448	−0.1443	−0.0945	−0.1037
Food processing	−0.3660	−1.3552	−0.0278	0.0603	−0.0927	−0.2217	−0.3474	−0.2902	0.0094	−0.2743
Foods production	0.1291	−0.2507	0.6980	−2.9422	−1.8557	−0.4720	−0.4829	−0.2800	−1.8059	−0.2507
Beverages production	−0.0468	−0.0995	−0.4641	2.7772	2.6827	1.1314	0.3367	0.0794	3.3679	−0.2320
Tobacco processing	−0.2889	−0.2757	−0.0070	0.4050	0.8429	0.1582	0.0545	0.0744	0.2036	0.0622
Textile industry	0.1749	1.7818	0.6028	1.4819	1.7088	1.4763	1.2443	1.0504	1.0830	1.0578
Garments and other fiber products	0.0021	−0.0997	−0.0036	−0.0670	−0.0124	−0.0274	−0.0320	−0.0170	−0.0427	−0.0448
Leather, fur, feather and related products	−0.3153	−0.0680	−0.9938	0.7243	0.4849	0.1160	0.0529	0.1128	0.0929	0.1191
Timber processing, bamboo, cane, palm and straw products	−0.0929	0.0162	0.1872	−0.4666	0.3169	0.1526	0.1256	0.0644	0.0976	0.0933
Furniture manufacture	−0.0160	0.0028	0.0467	0.0250	0.0315	−0.0117	−0.0038	0.0194	0.0156	0.0332
Papermaking and paper products	1.3075	3.4256	9.2604	−10.1695	−8.8556	−4.3419	−2.7540	−2.6455	−2.4953	−2.1185
Printing and record media reproduction	−0.0950	−0.1046	0.0017	−0.0176	−0.0241	−0.0198	−0.0361	−0.0227	−0.0349	−0.0139
Manufacture of articles for culture, education and sport activity	−0.0385	−0.1085	−0.1955	0.2100	0.1244	0.0665	0.0308	0.0303	0.0172	0.0212
Petroleum processing and coking	−0.8040	−6.9767	−0.0846	3.1564	0.0922	0.0794	0.4539	0.2705	0.0856	−0.0772
Raw chemical materials and chemical products	−0.0725	6.7127	3.3346	−9.6518	−5.0983	−2.3251	−1.2484	−1.4777	−0.2538	−2.5883
Medicines and pharmaceutical products	0.1617	0.1554	0.1328	−0.9806	−1.8819	−1.3802	−1.2787	−1.1438	−0.9243	−0.8658
Chemical fibers	0.0780	0.0718	−0.0119	−0.0471	−0.7338	−0.0079	−0.0074	−0.1358	−0.1509	−0.1074
Rubber products	−0.0294	−0.0202	0.0633	−0.2675	−0.1972	0.0728	0.1296	0.0970	0.1259	0.1080
Plastics products	−0.1363	−0.1055	0.0329	0.0744	0.1472	0.0985	0.0912	0.1315	0.1200	0.0752
Nonmetal mineral products	1.8100	4.7442	2.9828	2.9198	−1.1396	2.0778	3.1691	3.1623	3.3867	3.5037
Smelting and pressing of ferrous metals	4.4172	34.4373	45.3059	−32.7457	−33.7544	−10.5416	−2.9454	−0.4330	0.0771	2.0346
Smelting and pressing of nonferrous metals	0.3862	0.0351	1.0490	−0.9258	−0.5611	0.0647	0.0400	−0.0358	0.1895	−0.1117
Metal products	0.0902	−0.3068	−0.0876	−0.2477	−0.2444	−0.1745	−0.1801	−0.1334	−0.1259	−0.1382
Ordinary machinery	0.0015	0.1211	−0.1842	−0.7928	−1.1767	−0.8702	−0.7434	−0.6169	−0.6143	−0.5547
Equipment for special purpose	0.0259	−0.0599	0.1273	−0.7443	−0.9174	−0.5164	−0.4552	−0.4069	−0.4356	−0.4119
Manufacture of transport equipment	−0.1604	−0.0250	0.0115	0.1704	−0.0758	−0.0282	0.1161	−0.1078	−0.4278	−0.7975
Electric equipment and machinery	−0.0130	0.0013	0.0067	−0.0110	0.2799	0.2164	0.2549	0.2165	0.1199	0.1687
Electronic and telecommunications equipment	−0.9413	−3.0196	−1.4669	3.4186	9.0123	4.8310	5.1095	4.1471	4.2425	5.4801
Instruments, meters cultural and office machinery	0.0661	0.0750	0.0524	−0.2607	−0.1056	−0.0580	−0.0436	−0.0216	−0.0288	0.0380
Electric power, steam and hot water production and supply	−4.6325	−3.4488	−10.5430	7.4818	−9.2427	−9.3648	−5.6569	−7.2560	−6.5046	−4.3706
Gas production and supply	4.6284	0.4317	0.6539	−0.2719	0.0528	−2.0769	−0.8797	−89.8924	−75.9928	−2.3406
Tap water production and supply	0.0129	0.4224	0.8559	−0.7789	−1.7382	−1.0511	−0.4228	−0.2974	−0.1327	−0.0422

contribution degree of intensity effect was petroleum processing and coking with −4.44%. chemical fiber and cultural, educational and sports articles came next with contribution of −0.88% and −0.02 in separate. The contribution degrees of intensity effect of the rest sub-sectors were all above zero (Table 4).

For deep understanding of contribution degree of structure effect, Eq. (13) is imported. It is centralized as:

$$\delta_i = \frac{\lambda_i \times (-1)^{\alpha}(S_i^0 - S_i^t)}{S_i^0} \quad (i = 1, 2, \ldots, 36), \quad (t = 1, 2, \ldots, 11) \tag{13}$$

α is a dummy viability. If i is an energy-intensive sub-sector which energy intensity above 0.5, then $\alpha = 2$, otherwise it is 1 [25]. During the sampling time, the largest average value with 3.08% of contribution degree of structure effect came from electronic and telecommunications equipment. The main reason could be the fast decline of energy intensity of the sector which reached the lowest point in 2003 among all the sub-sectors when its added value increased by 8.81% than 1993, but the added value share increased from 2.84% in 1993 to 6.26% in 2003. The contribution degree from gas production and supply with −16.57% is the smallest. As the energy intensity of this sub-sector was comparably high, the added value of industry also increased by 7.49% than 1993 and kept rising continuously. Its growth rate was just next to electronic and telecommunications equipment and its proportion to the total output of industry went up constantly. In terms of time series, the sub-sector that contributed most to structure effect distributed dispersedly in different years. They were gas production and supply, smelting and pressing of ferrous metals, electric power, steam and hot water production and supply, electronic and telecommunications equipment and petroleum

and natural gas extraction. The smallest contribution degrees on structure effect were from electric power, steam and hot water production and supply, petroleum processing and coking, smelting and pressing of ferrous metals and gas production and supply in different years.

5. Conclusion and further studies

Based on the data of added value and energy consumption of 36 industrial sub-sectors from 1993 to 2003, this paper adopts the improved energy index decomposition method to analyze the structure and intensity effects that affect energy intensity of sub-sectors. It helps to outline the shape that before 1998 the structure effect had been declined while the intensity effect kept declining during the whole sampling time. Also taking 1998 as the demarcation point, it can also be found that before 1998 the contribution from the sub-sector structure change was less than the enhancement of energy intensity of sub-sector itself and since 1999 the situation totally reversed. During the sampling period, sub-sectors of electronic and telecommunications equipment and gas production and supply separately contributed most and least to the aggregative structure effect, and sub-sectors of raw chemical materials and chemical products and petroleum processing and coking separately contributed most and least to the aggregative intensity effect.

In 2002, China's energy efficiency, by calculating on the exchange rate, was equal to America's 1/3, Germany's 1/6, Japan's 1/12 and the world average's 1/2 [25]. Therefore, the gap which has plenty space for decline is still large and needs to be filled with especially for industrial energy intensity. The reality is that China is facing daunting challenges to address the shortage of per capita energy, environment pollution and ecosystem degradation with its remarkable economic growth. The Chinese Government's 11th five-year plan for energy conservation 2010 calls for improved efficiency by 20%. The historical experience from developed countries has proved that the energy intensity will not spontaneously decline in the wake of the increase of economic. The energy intensity of the whole industry would reduce only by keeping increasing the energy intensity of industry's sub-sectors, reforming industrial structure, enhancing the proportion of low energy consumption sub-sectors, decreasing the ratio of high energy consumption sub-sectors and accelerating the establishment of a standard scientific evaluation system on energy consumption to meet energy and pollution targets.

The article mainly focuses on studying the sub-sectors of the industry which each one can be further divided into different units of enterprises. Hence further study will derive from the microcosmic level to take the enterprises' energy intensity as observation variable, obtain data through practical survey, dig up the effects on the change of enterprise's energy intensity and advance further applied suggestions.

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Reference

[1] NBS-National Bureau of Statistics of China, 1981–2004 NBS-National Bureau of Statistics of China, China Statistical Yearbook 1981–2004, China Statistic Press, Beijing (1981–2004).
[2] NBS-National Bureau of Statistics of China, 1991–1996 NBS-National Bureau of Statistics of China, China Energy Statistical Yearbook 1991–1996, China Statistic Press, Beijing (1997, 2000, 2006).
[3] Smil, V. China's Energy. Report Prepared for the U.S. Congress Office of Technology Assessment;1990:Washington, DC.
[4] Kambara T. The energy situation in China. China Quart 1992;131:608–36.
[5] Sinton JE, Levine MD. Changing energy intensity in Chinese industry: the relative importance of structural shift and intensity change. Energy Pol 1994;22:239–55.
[6] Lin X, Polenske KR. Input–output anatomy of China's energy use changes in the 1980s. Econometrica 1995;7:67–84.
[7] Zhong XZ. Why did the energy intensity fall in China's industrial sector in the 1990s? The relative importance of structural change and intensity change. Energy Econ 2003;25:625–38.
[8] Karen F-V, Jefferson GH, Liu H, Tao Q. What is driving China's decline in energy intensity? Resour Energy Econ 2004;26:77–97.
[9] Han Z-Y, Wei Y-M, Ying F. Research on change features of Chinese energy intensity and economic structure. Appl Stat Manage 2004;1:1–6.
[10] Divisia F. L'indice monetaire et la theorie de la monnaie. Revue Divisia' Economie Politique 1925;39:842–64.
[11] Hulten CR. Divisia index numbers. Econometrica 1973;41(6):1017–25.
[12] Boyd GA, McDonald JF, Ross M, Hanson DA. Separating the changing composition of US manufacturing production from energy efficiency improvements: a Divisia index approach. Energy J 1987;l8(2):77–96.
[13] Boyd GA, Hanson DA, Sterner T. Decomposition of changes in energy intensity—a comparison of the Divisia index and other methods. Energy Econ 1988;10(4):309–12.
[14] Liu FL. Decomposition analysis applied to energy: some methodological issues. Ph.D. Thesis, Department of Industrial and Systems Engineering, National University of Singapore, Singapore;2004.
[15] Park SH. Decomposition of industrial energy consumption-an alternative method. Energy Econ 1992;14(4):265–70.
[16] Ang BW, Liu FL. A new energy decomposition method: perfect in decomposition and consistent in aggregation. Energy 2001;26(6):537–48.
[17] Ang BW. Decomposition analysis for policymaking in energy: which is the preferred method? Energy Pol 2004;32:1131–9.
[18] Ang BW. The LMDI approach to decomposition analysis: a practical guide. Energy Pol 2005;33(7):867–71.
[19] Ang BW, Na Liu. Energy decomposition analysis: IEA model versus other methods. Energy Pol 2007;35(3):1426–32.
[20] Ang BW, Zhang FQ. A survey of index decomposition analysis in energy and environmental studies. Energy 2000;25(12):1149–76.
[21] Törnqvist L. A memorandum concerning the calculation of Bank of Finland consumption price index (in Swedish), unpublished memo, Bank of Finland, Helsink;1935.
[22] Sato K. The ideal log-change index number. Rev Econ Stat 1976;58:223–8.
[23] He J-K, Zhang X-L. Analysis of China's energy consumption intensity reduction tendency during the 11th five-year-plan period. China Soft Sci 2006;6:33–8.
[24] Li PSD. Empirical analysis of the strategic alliance of MNEs on Chinese technological progress. Fin Trade Res 2006;5:25–32.
[25] Minliang Z. The change of industry structure and sustainable development in China. Reform 2002;2:10–7.